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RESEARCH ARTICLE

Through History and Technique: Pier Luigi Nervi on Architectural Resilience

Micaela Antonucci* and Sofia Nannini†

Along with his professional work as engineer, architect and builder, Pier Luigi Nervi (1891–1979) was also an adjunct professor at the University of Rome and a prolific writer. Through his writings, his views on architectural history can be traced and framed as part of a wider discourse concerning what he termed architectural 'constants'. Moreover, his interest in the architecture of the past led him to identify what could be defined as 'architectural resilience', that is, an ever-evolving relationship between building forms, techniques and materials. Seeing technique as preceding form, he examined structural elements that resisted the passage of time and outlasted building typologies and styles. Combining Nervi's published and unpublished lecture notes with his personal collections of architectural postcards, photographs and his writings, this article explores Nervi's search for a *stile di verità* (truthful style) through the lens of architectural resilience. With its focus on the resilience of structural elements, the article also places the engineer's use of reinforced concrete in the particular historicity of this material and in the longer continuum of construction history.

Introduction

Speaking at Harvard University in April, 1962, the Italian engineer Pier Luigi Nervi (1891–1979) underscored the need within contemporary architectural practice to 'determine whether there exists a rapport between building technology and architectural aesthetics'. He then asked his audience to seek answers in history, to 'investigate whether among the great variety of building techniques developed by mankind there exists a number of constants' (Nervi 1965a: 1).[1] For example, referring to the grandiose hypostyle hall at Karnak, he wondered if 'the strong architectural expression created by the excessive closeness of the large columns was not the inevitable product of the available constructional techniques rather than the result of an architectural thought or volition', or if the 'short free spans' of the Parthenon were 'directly dependent on the flexural resistance of the horizontal masonry blocks' (Nervi 1965a: 12–13).[2] His reading of ancient architecture was based primarily on the study of materials and structural features: especially when describing his own buildings, Nervi explained his choices by highlighting the distinctive features of reinforced concrete and the way in which this material of modernity could best be used to blend aesthetics and technology (Nervi 1955).

Nervi's quest for an architecture that would mirror the laws of physics led him to examine structural examples from throughout history that were true to their materials and had lasted for centuries. His interest in the history of architecture may seem surprising, as he was not a historian and was openly critical of the historian's role. During his lessons at the University of Rome, he claimed, 'A historian does not create. … What does a historical architectural culture serve here?' (Einaudi 2010: 124). Yet the way in which he looked at the architectures of the past was not superficial. He delineated what might be defined as 'architectural resilience', that is, the ever-evolving relationship between building forms, techniques and materials. Because he saw technique as preceding form, he focused on structural elements that had resisted the passage of time, persisting despite changing building typologies and styles.

During his long and successful career, Nervi combined his activity as an engineer with that of a theorist and teacher. In addition to working as a designer and builder, he wrote several books on architecture and published articles in some of the most important Italian and international journals of his time (*Domus*, *Casabella*, *L'Architecture d'aujourd'hui*, *Concrete* and others). Recent research on Nervi's prolific writing activity has called attention to his efforts to create a bridge between the professions of the engineer and the architect, the relationship between which had become particularly complex during the post-war years (see Pace 2014: xi–xv).[3] Yet so far, these studies have not analysed Nervi's ideas with respect to the education of architects and engineers and the role of history in teaching and design, and few have investigated his role as a teacher (Antonucci 2010; Trentin and Trombetti 2010; Trentin 2012). This article examines Nervi's published (Einaudi 2010) and unpublished lecture notes (MAXXI APLN, ReD, R6/2, 1955–67), as well as his writings, together with his personal and original collections of architectural postcards and photographs,[4] whose role

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was pivotal both in Nervi's teaching and in his research activities. Thanks to these sources, the essay aims to make an original contribution to the body of knowledge about Nervi's work, in consideration of his search for a *stile di verità* (truthful style) through the lens of architectural resilience. This analysis focuses on three main issues: the role of architectural history in Nervi's teaching and design; Nervi's search for constants in architectures throughout history, which was related to his idea of 'building correctness'; and architectural resilience and the evolution of building techniques, with special attention to the historicity of reinforced concrete.

Nervi Teaches: Blending Architectural History and 20th-Century Building Practice

Between 1945 and 1962, Nervi was an adjunct professor of material technology and construction technique at the Faculty of Architecture of the Sapienza University in Rome, and was frequently asked to deliver lectures in universities and institutions in Italy and worldwide. Some traces of his passionate educational activity, aside from the notes collected by the Italian-American architect Roberto Einaudi, who was a student of Nervi during the academic year 1959–60 at the University of Rome (translated back into Italian and edited in Einaudi 2010), can be found in the Pier Luigi Nervi archive at the Museo Nazionale delle Arti del XXI Secolo (MAXXI) in Rome. Twenty undated pages of notes — probably those of a student or an assistant taken during one of his lectures in Rome — and a considerable amount of iconographic material that Nervi used during his lessons and conferences are of particular interest (MAXXI APLN, ReD, R6/2, 1955–67).

Through his teaching activity, Nervi was able to carry on the didactic tradition of the School of Engineering in Bologna, where he graduated in 1913, and in particular of two of his professors, the engineers Silvio Canevazzi and Attilio Muggia (Antonucci 2009 and 2010; Greco 2010). Canevazzi was a pioneer in the development of both construction science and the use of reinforced concrete in Italy, and among the first scholars to introduce construction theories related to this new technology into teaching programmes. Through Canevazzi, Nervi acquired the conviction that results obtained via the application of theoretical formulas had to be consolidated and confirmed by experimental investigation of materials and models, by real-life observation, and through an intuitive understanding of the static behaviour of buildings. Muggia was one of Canevazzi's most brilliant students and among the protagonists of Italian engineering in the early 20th century, able to align his prestigious scientific and educational activity with the prolific career of a professional builder. Since 1898, he had been the concessionaire for central Italy of the building system patented in 1892 by the Frenchman François Hennebique, and in 1908 he founded the Società anonima per costruzioni cementizie, a building firm — in which Nervi worked between 1913 and 1923 — that soon became well known for using and experimenting with reinforced concrete. In his teaching of architectural engineering at the School of Bologna, Muggia used to dedicate many lessons to the history of architecture. He also wrote a book for his students entitled *Storia dell'architettura: dai primordi ai giorni nostri* (History of Architecture from the Beginnings to the Present) in order to 'reconstruct the evolution of architecture through time, in relation to the evolution of the various civilisations and the progress of constructional means' (Muggia 1933: v). Clearly, Nervi must have learned from Muggia both how to build with reinforced concrete and the importance of knowing the evolution of architectural forms and building techniques. On the one hand, Nervi's academic education was deeply influenced by the long 19th-century 'polytechnical movement', whose 'polytechnical training believed in the unity of the arts of construction' (Saint 2005/2006: 25). On the other, both Nervi and his professors may also have been influenced by the legacy of Jean-Baptiste Rondelet and his views on construction history (Middleton and Baudouin-Matuszek 2007; Middleton 2013) and by Eugène Emmanuel Viollet-Le-Duc's theory of an architecture 'relying on novel principles of structure' (as quoted in Mallgrave 2006: 527).

In contrast to his contemporary practice, which focused solely on technique, Nervi would customarily open his academic lectures, as his master Muggia used to do, with examples taken from the history of architecture. Although the ultimate goal of his lessons was to teach his students how to design and calculate concrete structures, above all he highlighted the importance of understanding the structural behaviour of buildings past and present before designing new architectures. Nervi's unpublished lecture notes from his tenure at the University of Rome offer unparalleled insight into how he sought to convey to students his ideas on architecture — the same ideas that he more systematically debated in his writings throughout his career. At the beginning of the lecture notes he tackles one of his fundamental principles, that is, the connection between 'aesthetics and technology' in architecture. He believed analysing the architecture of the past is the most efficient way to understand this synthesis. Thus, Nervi highlighted some architectural works that he considered to be models: among them, the dome of Santa Maria del Fiore built by Filippo Brunelleschi, which he proclaimed 'the perfect example of a technically perfect architecture, that for this very reason is also beautiful'; the Pantheon and the Basilica of Maxentius in Rome; and an assortment of Gothic architectures. Throughout these lessons, Nervi reiterated again and again the need to analyse both ancient and modern architectures:

> If you could understand statics, I do not say as Brunelleschi or the architects of the Pantheon did, but if you could at least go closer to that level of knowledge and if you could simultaneously take advantage of the possibility of construction mechanics, of the possibility of materials and of technique, a future of endless splendour would await you. (MAXXI APLN, ReD, R6/2, 1955–67)

Nervi's goal, like that of his master Canevazzi, was to persuade students that mathematics is not enough when it comes to structural design. Actually, modern building engineering is considered to have developed only in the mid-18th century, with the work of Giovanni Poleni (1683–1761) on the dome of St. Peter's Basilica in Rome (Greci 2003: 85). Therefore, Greek and Roman builders, and even Renaissance architects, did not have the mathematical and scientific tools modern engineers do — yet they were able to build great and monumental architecture. Nervi admired them. A recurring example he offered to his students was the Basilica of Maxentius in Rome (**Figure 1**):

> This is a drawing of the original plan of the Basilica of Maxentius. … One could have philosophised on the architectural beauty of the walls arranged in this direction, on the thickness of that wall down there … One would have discovered all these peculiarities that, entering and looking in a superficial way, do not recall a static issue; yet, if you feel like looking deeper, they are all defined by static matters. … One who enters the Basilica of Maxentius and does not observe with attention does not understand all that. (MAXXI APLN, ReD, R6/2, 1955–67)

It must have been a shock for Nervi's students to attend such lessons. They were studying with an expert known worldwide for his knowledge of reinforced concrete, one of the most daring builders of the 20th century, and he was claiming that those who built ancient Roman masonry vaults or Gothic stone cathedrals were technically superior. In his lessons at 'La Sapienza' in 1959–60, as recorded by Roberto Einaudi, he could lecture about concrete formworks and at the same time discuss the dome of Santa Maria del Fiore in Florence (Einaudi 2010: 80). Indeed, the study of the cracks within Brunelleschi's dome was one of the first empirical studies that Nervi conducted as a professional, published in the essay titled 'Considerazioni sulle lesioni della Cupola di Santa Maria del Fiore e sulle probabili cause di esse' (Considerations on the Cracks of the Dome of Santa Maria del Fiore and on Their Possible Causes). In it, he claimed that the study of such a complex structure must be driven by empirical analysis (Nervi 1939). This analysis was for him a paradigm that he used to explain the physical balance inside structures, which is usually quite different from the mathematical balance expressed by equations. For Nervi, Brunelleschi's work represented one of the most important examples of the primacy of intuition and static sensibility over mere mathematics (**Figure 2**).

Nervi's cautious stance in regard to construction mechanics, which, to him, devalued the job of the builder and negated the effort of thinking and meditating, echoed the opinion of some of his most celebrated colleagues. The French engineer and pioneer of prestressed concrete Eugène Freyssinet (1879–1962), for example, famously asserted that 'when intuition contradicted the results of a calculation, I would have the calculation redone, and at the end of the day, it was always the calculation that was wrong' (quoted in Forty 2012: 288). A similar position was adopted by the Swiss engineer Robert Maillart,

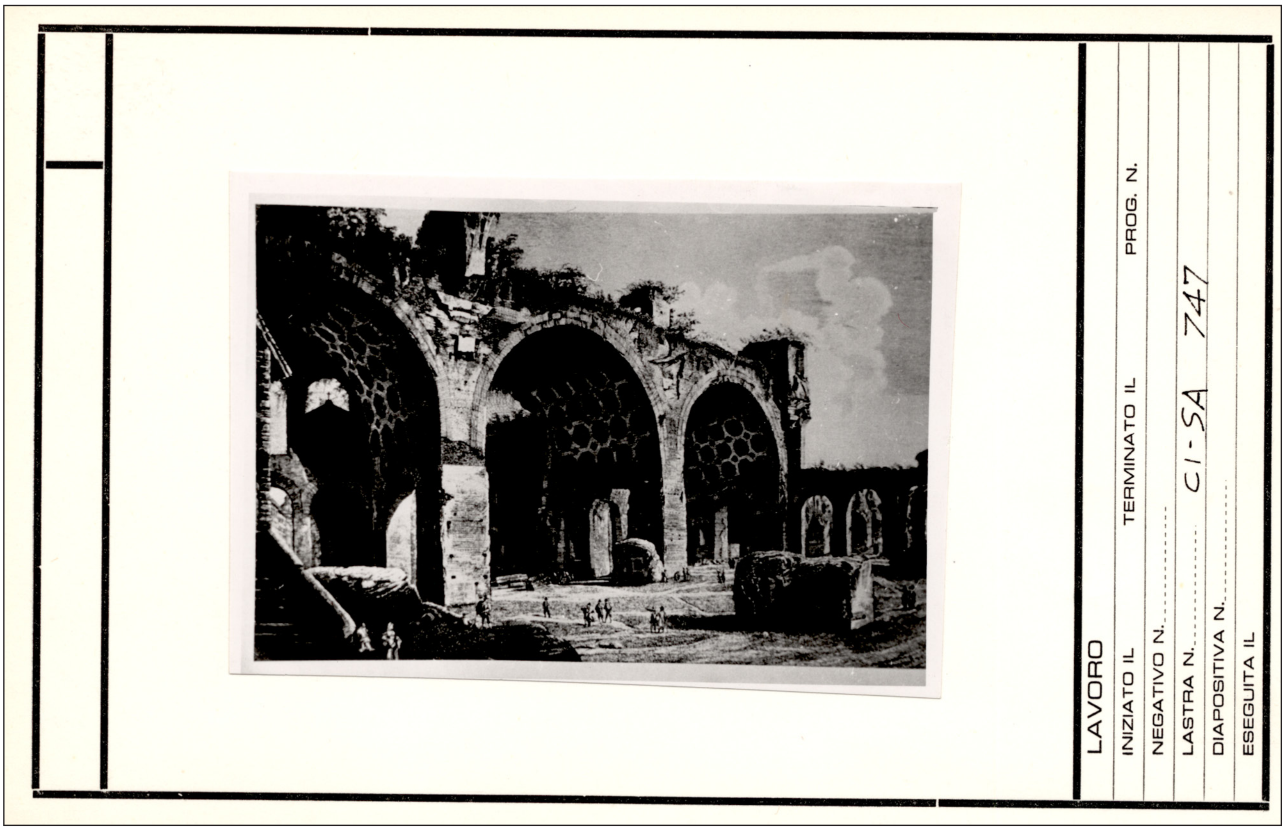

Figure 1: Basilica of Maxentius in Rome. Photographic index card. Collezione MAXXI Architettura, Archivio Pier Luigi Nervi, Museo Nazionale delle Arti del XXI Secolo, Rome.

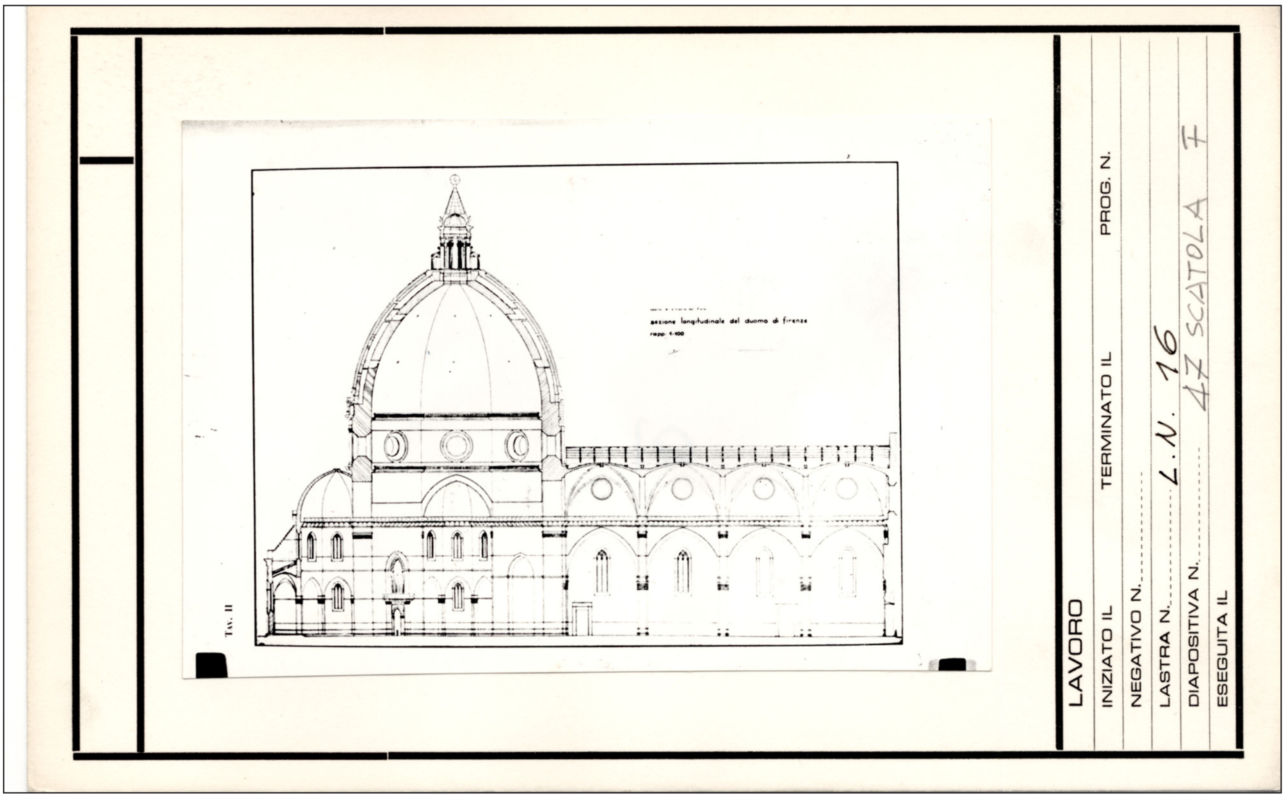

Figure 2: Santa Maria del Fiore in Florence. Photographic index card. Collezione MAXXI Architettura, Archivio Pier Luigi Nervi, Museo Nazionale delle Arti del XXI Secolo, Rome.

who 'spoke so strongly about the dangers of theories and codes' (Billington 1979: 47). Nervi, just like Freyssinet and Maillart, insisted on the importance of practice and of what he called 'static sense' — that is, the ability to have an intuitive vision of static reality in structural design (Nervi 1955: 6–7) — as well as on the dangers of standardisation in the engineer's building activity. It is significant that three of the most creative engineers of the 20th century gave more attention to intuitive and practical knowledge than to mere mathematical theory, despite their strong grounding in theory and mathematics, and, as a consequence, that they considered the architecture of the past as a still-valid model.

The Role of the Architect and the 'Immutable Forms in Architecture': From Vitruvius to Nervi through Alberti

Reading his writings and lecture notes, it is easy to understand how, according to Nervi, a good architect is both an artist and technician with a vast and eclectic education, whose work encompasses all branches of knowledge. Despite being a pioneer of modernity, Nervi's vision of the architect was tightly bound to the resilient Vitruvian ideal. He referred to this model both explicitly, often quoting from Vitruvius' *De architectura*,[5] and also indirectly, as reinterpreted in the influential architectural treatises of the Renaissance. In his second book, *Costruire correttamente* (1955), Nervi writes,

> It is easy to see how elevated and complex the profession of the architect is … All the branches of knowledge merge in it and there they have to find a balance that can express unmeasurable and scarcely definable artistic, moral and social values, and moreover in a form that — in order to obey the essential feature of the building works, that is, their duration in time — has in itself something absolute (Nervi 1955: 6).

These words may recall those of the Renaissance architect and theorist Leon Battista Alberti, as he described the architect's features in his *De re aedificatoria* (Alberti 1989: 475). Nervi knew that such a professional figure was mainly an ideal — easily described in theory but difficult to find in practice. This was partly due to the distinction between the building engineer and the architect within 20th-century Italian academia, promoting two detached faculties with similar programmes — a widespread separation whose roots may be found in the increasing specialisation that new materials required due to 'the growing complexity of structures and the need for specialised calculations' (Saint 2005/2006: 26; Saint 2007). Despite the 'widening gulf between architectural and engineering skills' (Saint 2005/2006: 26), the true architect, for Nervi, was firstly a builder whose academic education should provide the 'scientific and construction basis and above all a trained intuition and technical awareness' (Nervi 1966b: 515–16).

Echoing Vitruvius's *firmitas*, *utilitas* and *venustas*, Nervi recognised three main features for a correct architectural result: *statica* (statics), *funzionalità* (functionality) and *economia* (economic efficiency) (Nervi 1945: 18–20).

Beauty — the Vitruvian *venustas* — is not explicitly included in Nervi's triad, yet he saw it as the result of the merging of the three categories. In Nervi's opinion, the elements needed for a good project were functionality and structural truthfulness, the proper choice and use of materials, and economic efficiency. All these features were the result of the 'proper proportioning of the sizes and relationship of spaces, the richness of ornamentation and the preciousness of the materials with respect to the purpose for which the buildings will be used' (Nervi 1965a: 3). These words mirror Alberti's definition of beauty as *concinnitas* — that is, proportion and balance among all parts. The unstated, though necessary, category of 'architectural beauty' derives from what Nervi described as 'building correctness', which is directly linked to the definition of a 'truthful style' (Leoni 2010; Antonucci 2014). In Nervi's view, 'building correctness' was a necessity in pre-modern architecture. Ancient architects could not design what he called 'building acrobatics', because the materials and techniques they used did not allow it. Consequently, the architecture of the past is the perfect model for a correct design in modern times:

> With bricks, stone, timber, lime, it is impossible not to be correct builders, because those materials do not allow acrobatics. ... Building acrobatics is against architectural beauty. ... In the past, this was a necessity. No builder would have dared to make an excessive cantilever because it would have fallen down. (MAXXI APLN, ReD, R6/2, 1955–67)

In his quest for beauty, Nervi took lessons from both the architects and the buildings of the past. He discovered a 'superhistorical lesson, a lesson of [those] constants that lead architecture of all times back to the measure of Man and his relationship with matter' (Leoni 2010: 166). Throughout his career, he used images and photographs of buildings, which he collected by the thousands and assembled on index cards as fotoschede, to delineate the constants that defined a fil-rouge within architecture throughout history. The images he collected ranged from ancient Egyptian and Greek temples to Gothic cathedrals, from great Renaissance domes to modern structures like the Galerie des Machines in Paris and the Twin Towers in New York. Many of these images were also collected in the so-called albums, used both for promotional and didactic purposes. This collection was at the core of Nervi's didactic method, as he used to project the images in his lectures; but his focus in presenting these exemplars was not strictly historical, and his lectures were by no means chronological. Nervi organised his fotoschede and albums — now in the Pier Luigi Nervi archive at MAXXI — according to each topic, mixing the selected historical architectures together with his own works (**Figure 3**).

Figure 3: A page from Pier Luigi Nervi's albums. Collezione MAXXI Architettura, Archivio Pier Luigi Nervi, Museo Nazionale delle Arti del XXI Secolo, Rome.

His aim was to establish a 'genealogy' linking different times and geographies, interpreted relative to technical systems and not as a mere repetition of shapes belonging to different periods and styles (Acciai and Collotti 2012: 102). Nervi's unsystematic and unscientific collection of architectural images had almost the features of a typological study, as it was more closely related to etymology than to classification.[6] Indeed, it may be stated that Nervi was involved in a sort of 'etymological' study of architecture, as if he were trying to find some common elements among a wide network of historical structural examples. Certainly, this collection offers a visual impression of Nervi's architectural interests, the importance of which may be compared to that of a Renaissance author's sketchbook. His method was not intended to investigate the mere forms of architecture, neither did he wish to trace the actual authors of the buildings; the only name he persistently quoted was that of Brunelleschi, defined as a 'hero' because of his inventiveness in building the dome of Santa Maria del Fiore.

Nervi used his monumental collection of architectural images constantly in his lectures, conferences and publications. His concept of an architecture moving towards immutable forms and characters, first presented in his book Scienza o arte del costruire? Caratteristiche e possibilità del cemento armato (1945), prompted a heated debate within the architectural profession which played out on the pages of Domus between 1949 and 1950 (Pica 1949; Nervi 1950; Nervi 2014a: 125–30).[7] As the architect and critic Agnoldomenico Pica disputed Nervi's idea of 'immutable forms', he acknowledged that scientific theories are prone to change and, as a result, ideas on architecture tend to vary and evolve. Yet, he stressed, 'certain cornerstones will not change any longer'. He believed these cornerstones — or constants — were the laws of physics that ground each structure (Nervi 2014a: 126). Reading these words, Nervi's concept of resilience becomes clearer: architectural forms are not always resilient, because they constantly change, but there is a resilience in structure, because of the unvarying laws of nature and physics. These ideas were repeatedly reaffirmed by Nervi in other writings and public debates (Nervi 1946; Nervi 1963–64; Nervi 1965b). The debate in 1961–62 on aesthetic forms and physics laws with the art critic and philosopher Gillo Dorfles and the mathematician Bruno de Finetti, published in the journal *Civiltà delle macchine* in 1966 (Nervi 1966a) and in a chapter in *Aesthetics and Technology in Buildings* of 1965, titled 'The Foreseeable Future and the Training of Architects' (Nervi 1965a: 183–99), was particularly significant. Yet Nervi's ideas about the distinctive resilience of the law of statics — shaping structures that show the inner stream of forces and that, at the same time reach an expressive and aesthetic balance — also explored notable building materials. Beginning in the last decades of the 19th century and continuing throughout the 20th, the resilience of traditional architectural structures was challenged by an innovation that broke with all previous architectures: the use of reinforced concrete, the 'trademark of the new architecture' (Giedion 1954: 320).

A Material Resilience: Concrete in History

The medium of concrete is at once both 'unhistorical' and deeply rooted in construction history, dating back to the Roman use of *caementum* (Forty 2012: 86). While recent studies have shed light on the long history of concrete and its relationship to the technical evolution of lime and mortar in the modern industrial age (Gargiani 2013; Aprea 2016), the history of reinforced concrete is still very young, having begun with the patented inventions of Joseph Luis Lambot, in 1855, and Joseph Monier, in 1867 (Collins 1959: 60). Despite recurring doubts regarding the historicity of reinforced concrete, there is no question that architects like Auguste Perret, Le Corbusier and Louis I. Kahn strove to create a new language for this apparently new and 'unhistorical' material. The quest for a 'classical language in reinforced concrete' (Summerson 1963) was also a frequent topic for Nervi:

> How will it be possible to define the new elements, which, answering to necessity or functional demands, will form a new vocabulary of aesthetic expression in architecture, in the same way that cornices, entablatures, capitals, columns, rustication blocks, window architraves, and circular or pointed arches constituted the words of the architectural language of the past? (Nervi 1965a: 7–8)

As the 20th century unfolded, new features were added to the structural capacities of reinforced concrete, such as prestressed cables and high-resistance cements. These technical advances eventually led to the creative and architectural exploitation of the material, especially by engineers, during the post-war years in particular. Alongside Nervi, Riccardo Morandi and Sergio Musmeci were other leading figures in the Italian context (Iori and Poretti 2014).

Seeking connections between concrete and history, some of the aforementioned architects focused their attention on the surface of this material. Auguste Perret claimed,

> It is the use of wooden formwork that gives reinforced concrete the appearance of carpentry on a grand scale, and makes it resemble the architecture of the ancient world, in the sense that such architecture imitated building in timber, while reinforced concrete makes use of timber. (Britton 2001: 241)

Not only was Le Corbusier fascinated by Greek, Roman and Byzantine architecture, as proven by his carnets de voyages and the chapter called 'The Lesson of Rome' in *Vers une architecture* (Le Corbusier 1923), but the Swiss architect may have begun his quest towards the rough surface of concrete when he visited ancient ruins during his voyages, which appear to have inspired him as if to recreate the 'image of an artificial ruin' (Gresleri 1988). Moreover, not only did he experiment with formworks and the so-called *béton brut*, but he also referred to his *sculptures moulées* as being influenced by the '"ornamented construction" of the walls of ancient monuments' (Gargiani and Rosellini 2011: 36). Similarly, Kahn sought perfection in the details of the concrete structure of the Salk Institute in La Jolla, California (1959–65) by highlighting the joints (Rosellini 2014: 122). Beyond surface and decoration, Kahn was particularly inspired by the great Roman monumental complexes, such as Hadrian's Villa at Tivoli, which were his models for reaching a 'contemporary monumentality starting with the potential of new materials' (Gargiani 2014: 10).

Although Nervi's obsession with the surface of concrete was rooted more in economic than ornamental considerations,[8] it is important to examine his achievements in reinforced concrete in light of earlier architectural monuments. In the introduction to a new edition of Nervi's *Scienza o arte del costruire?*, Aldo Rossi stressed the coexistence of something both 'modern and ancient' in the engineer's projects (Rossi 1997: 4). Peter Collins also compared some of Nervi's vaults to 'certain sixteenth-century domes, such as that over the eastern apse of Sta. Maria in Carignano, Genoa' (Collins 1959: 171). Indeed, the rib pattern of the semi-dome in Hall B of Nervi's Torino Esposizioni in Turin (1947–54) is remarkably similar not only to the apse designed by Galeazzo Alessi in Genoa, but it may also be compared to older models, such as the apse of the Temple of Venus and Roma in Rome. Such resemblance is due to the fact that Nervi's semi-dome in Turin has been defined only by following the geometrical procedure of subdivision of a semicircle (**Figures 4** and **5**).[9] Just as with the immutable laws of physics, so with geometric properties: because they did not change over the centuries, a straight line could be drawn from Roman antiquity, through the Renaissance and to Nervi's concrete domes. Eventually, Nervi's great contribution to this persistent pattern can be found in the building technique he adopted, his patented system of precast *ferrocemento* (ferrocement) formworks, commonly named Sistema Nervi (the Nervi System). Thanks to this building process, he could update already known architectural forms to the technique of reinforced concrete, which in the hectic years of post-war Italy required extreme speed and ease of construction. Furthermore, this very system allowed Nervi to build an architecture of structural ribs, which are readily comparable to that of Gothic structures.

When analysing the making of the slabs for the Magazzino Ballette in the Manifattura Tabacchi (Tobacco Factory, 1949) in Bologna, Nervi stated that 'the plastic, and therefore architectural liberty is so complete that the design of the ribs adheres perfectly to static necessity and achieves considerable aesthetic expression' (Nervi 1965a: 32), thus alluding to one of his subjects of fascination: Gothic cathedrals, which were for him among the few examples of a true 'structural architecture' (Nervi 1963: 41). His fascination with the world of Gothic architecture was a recurring topic in his career. Not only has his system of prefabricated formworks been compared to the medieval building works for churches and cathedrals (Iori 2012a: 51), but Nervi referred several times to Gothic construction as an architectural model (Nervi 1957/58: 85–86; Nervi 1961; Nervi 1964, 594–95; Nervi 1965a: 6–7; Nervi 1969). Although he understood the main features of Gothic architecture and its structural system, he misunderstood others. For example, he was aware that the 'ribs [of Notre Dame] are not statically essential', thus anticipating Louis Grodecki's hypothesis on the non-static role of ribs (Grodecki 1996). Nevertheless, he would also claim that 'in the Gothic there is a system of compression, weight, stone, and harmony' and that 'in the rose window

Figure 4: Pier Luigi Nervi, Hall B of the Torino Esposizioni in Turin, 1947–54. Photo by Sofia Nannini, 2018.

of the Sainte Chapelle in Paris, the aesthetic and the statical lines cannot be separated' (Einaudi 2010: 80), perhaps ignoring the presence of iron chains within the walls of this chapel (Heyman 1995: 154).

Moreover, in the same post-war years, Nervi studied and patented a new type of structure — the ribbed floor slabs with an 'isostatic' pattern. Thanks to the key invention of his collaborator, Aldo Arcangeli, an engineer employed in Nervi's construction firm, this constructive process was based on the idea of placing the ribs of a slab according to isostatic lines in a system stressed by forces. Those lines define the main directions of tension and are tangent to the trajectories of the bending moments, on which the torques are zero. This invention, which Nervi experimented with for the first time in the projects for the tobacco factories in Bologna (**Figure 6**)

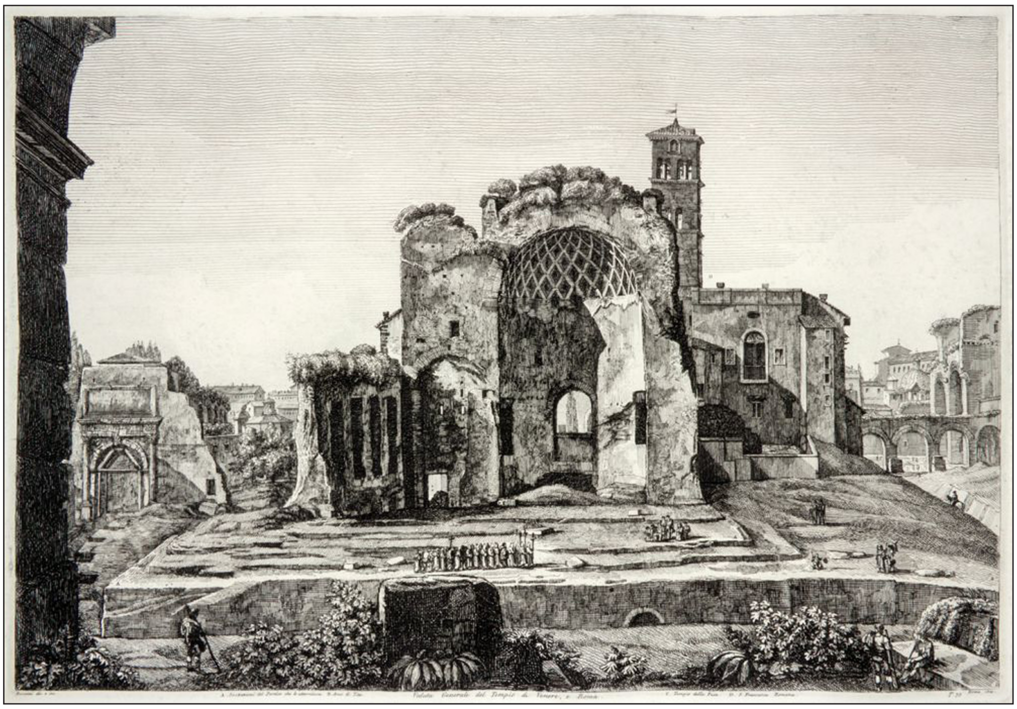

Figure 5: The Temple of Venus and Roma in Rome (Rossini 1829: pl. 72).

Figure 6: Concrete slabs of the 'Ballette' Building, Manifattura Tabacchi, Bologna. Photo by Micaela Antonucci, 2017.

and Rome (1949–51) and then applied in the Lanificio Gatti (Gatti Wool Factory) in Rome (1950–51), allowed him to go beyond traditional structural forms, mirroring his attraction to Gothic structures (Iori 2012b; Halpern, Billington and Adriaenssens 2013; Gargiani and Bologna 2016, 217–24; Antonucci and Nannini 2016). Using the vault of the Chapel of King's College in Cambridge as an example (**Figure 7a, b**), he stated that its 'ribs, which are reduced to pure decoration, form a pattern that suggests the isostatic lines of the principal stress, invisible physical realities that modern structural analysis and the experiences in photoelasticity have revealed to us in the past few decades' (Nervi 1965a: 7).

This anticipation of 20th-century concrete engineering is strikingly similar to the paradox that emerges within Peter Collins's analysis of the work of Auguste Perret; Collins notes that French Classical architects were striving for a 'trabeated and framed architecture' that could logically only be produced with a new material. Thus, 'it was not Perret who illogically imitated the seventeenth century, but the seventeenth century which illogically anticipated Perret, since it was he, rather than they, who made the structural expression and the structure expressed one and the same thing' (Collins 1959: 171). According to Karla Britton, Perret's lifelong work with concrete 'was born out of the idea that the material could mediate between the traditions of the past and the transitory present', thus becoming a 'governing norm through which he could express a continuity with previous conventions of construction' (Britton 2001: 11). If for Perret architectural form was essentially a structural form, the same can be said for Nervi. The Italian engineer saw within the history of architecture a long continuum of structural rather than formal solutions — a stream of technical achievements that evolved and improved over time. To him, even what was considered ornament or addition was generated for technical or logical reasons: 'the cornice is not a decoration — it is a constructive concept still valid today' (Einaudi 2010: 64). For Nervi, architecture was fundamentally a structural fact; therefore, he saw its aesthetic features as being the logical consequences of static and building solutions. This, he believed, was the most resilient and enduring characteristic of the entire architectural practice:

> It is difficult, if not impossible, to try to determine today whether the Roman bath scheme was born as a consequence of the invention of the groined vault and the possibility of neutralizing its thrust by the use of intersecting walls, or whether the necessity to create large interior spaces inspired a technician of genius to invent the groined vault. The unquestionable fact is that the technical solution of the thermal scheme permitted the creation of spaces of an architectural expression completely different from that obtained with the older techniques. The architectural expressiveness of the colossal hypostyle hall at Karnak is equally forceful but completely different from that of Roman baths. (Nervi 1965a: 5)

The 'technical solution' Nervi refers to — that is, the materials and the way they are used — is at the core of the building process and of architectural evolution. Because of, or thanks to, reinforced (and later, prestressed) concrete it was possible to go beyond the limited span between the columns of Karnak, and to make walls that equalled the Roman ones in load-bearing capacity, but with far

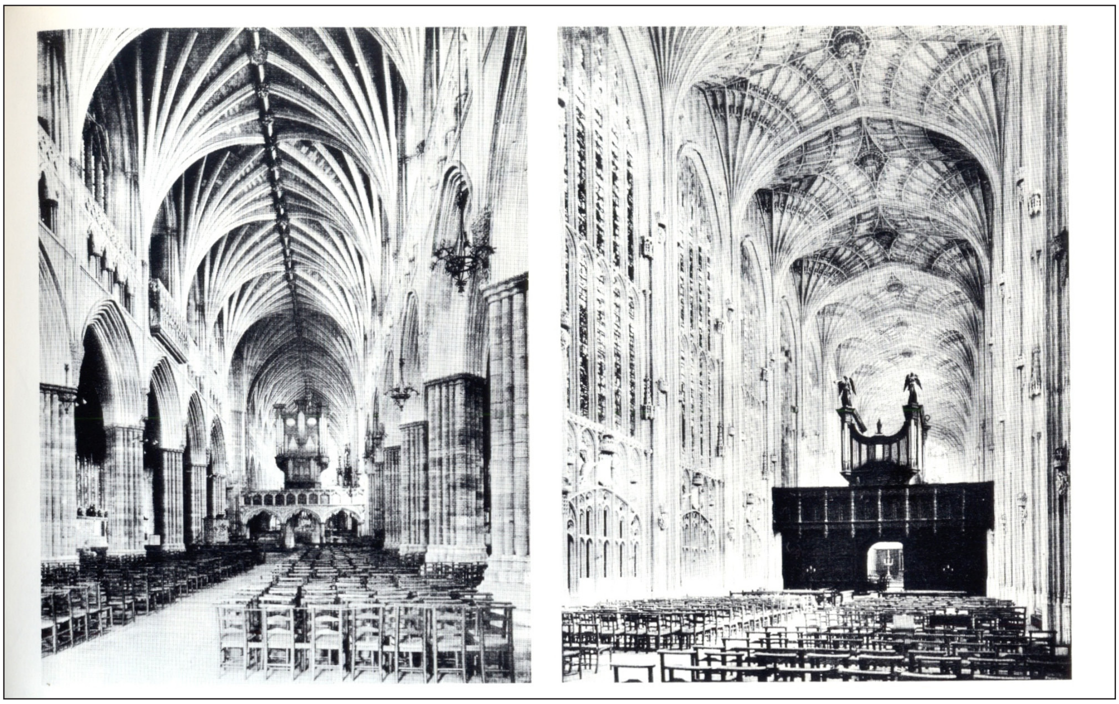

Figure 7a and **b:** Exeter Cathedral and King's College Chapel, Cambridge. P. L. Nervi, Aesthetics and Technology in Buildings, 1965a: 17.

less weight. Reinforced concrete allowed architecture to expand its dimensions, both in height and width, and eventually, it opened a path for the creation of new forms for all the traditional historical elements. Yet, notwithstanding his invention of ferrocement and the long list of patents he filed (Greco 2008), Nervi did not limit his construction practice to the banal application of standardised constructive systems. On the contrary, he tried to transcend the mere formal or material, and to find deeper building principles connected to geometry and statics. His architectural forms — even the most innovative ones, such as pleated or ribbed domes, transitional or variable section pillars, isostatic ribbed floor slabs — were the consequence of using these elementary principles, which were also to be found in the buildings of the past. As he said, the 'development of a new aesthetics … goes back to the principles of the most distant architectural periods' (Nervi 1965a: 22).

Editing a Universal History of Architecture: Towards a Material History

At the end of the 1960s, Nervi assumed the leadership of an innovative editorial project: the series Storia universale dell'architettura (Universal History of Architecture). Published in several languages by Electa, the series contains 15 volumes, the first editions of which were published between 1971 and 1977. These volumes, each edited by a different expert, cover the whole history of architecture, from *Architettura primitiva* (Primitive Architecture) by Enrico Guidoni to *Architettura contemporanea* (Modern Architecture) by Manfredo Tafuri and Francesco Dal Co. The series, which was to be an organic compendium of independent studies, was intended to combine scientific precision with a clear language accessible to the widest possible audience (Vanini 2012: 100). This project required a scientific coordinator of international prestige who could promote a new vision of architecture as a built object and not merely as an abstract idea. Nervi was the perfect choice to lead the series, and in this role he recruited internationally known scholars, including Peter Murray, Robin Middleton, David Watkin and Christian Norberg-Schulz, to contribute to the project.

The Storia universale dell'architettura project was also an opportunity for Nervi to reaffirm the importance of what he called 'the history of architectures' — that is, the history of material buildings and not only of immaterial styles — and to reassert the central role in architecture of the links between form, technique and function. As he stated in the foreword to the series, which was included in each volume, history had to overcome the 'visual feature' of architecture. It was necessary to understand that a 'built work' had to 'obey the objective constraints' linked to materials and building technique. Nervi thus put forth an idea of architectural resilience that spanned centuries, connecting static intuition, experience and materials. 'This hidden link', he added, might be that which merges the 'appearance' and 'substance' of all architectures throughout history (Nervi 1971–77). Nervi's idea of a longue durée that flows beneath architectural history can be traced through the material features of the buildings and the physical laws that underlie their structural principles. In other words, to invent the future, we must look to the past:

> Mankind is discovering in many ways and in many fields that new forms which are imposed by physical laws cannot be modified by whim. All this means that we are moving towards greater obedience to natural laws … If my conclusions are right, we are witnessing the birth of a style based on the truth, inspired by natural forms, characterized by purity of lines, by functional clarity common to all human endeavours and which being anchored to physical laws will evermore evolve towards a more complete final truth. Isn't it a marvellous promise? (Nervi 1963: 47)

Conclusion

Nervi developed a specific point of view on history and resilience within the architectural practice. His standpoint can be detected through his lesser-known professional role as teacher and theorist, evident in unpublished lecture notes, most probably taken by a student or an assistant and now collected in the Pier Luigi Nervi archive at MAXXI, and in the engineer's vast collection of images and photos of architectures. These documents show the major role played by architectural and construction history in Nervi's teaching activity. Nervi's views are rooted in his academic education, yet they not only echo the ideas of other 20th-century engineers, such as Robert Maillart and Eugène Freyssinet, but they also clearly have an affinity with the writing of Vitruvius and Leon Battista Alberti, especially in Nervi's definition of architectural constants. Architectural resilience can also be understood from a material point of view, particularly evident in Nervi's ideas about concrete. His unique use of reinforced concrete and its connection to past architectural examples place the engineer's research within a longer line of construction history. His later work as editor of the Electa series Storia universale dell'architettura (Universal History of Architecture) provides a definition of an architectural resilience through history, whose roots are to be found in the wise use of building materials and in the physical laws that shape architecture and its structures.

Notes

[1] Nervi held two conferences on April 10th and May 10th, 1962, at Harvard University, as he was awarded the Professorship of Poetry named after Charles Eliot Norton for the academic year 1961–62, together with architects Felix Candela and Buckminster Fuller. He was the first Italian to be granted this honour; only two other Italians after him were awarded the same title: Italo Calvino, in 1985–86 (whose lectures were later published in the famous book *Lezioni americane*) and Umberto Eco, in 1992–93. Nervi's lectures, translated from Italian into English by Roberto Einaudi, were published as *Aesthetics and Technology in Building: Charles Eliot Norton Lectures (1961–1962)* (Cambridge: Harvard University Press, 1965).

2 With the exception of the material cited from *Aesthetics and Technology in Buildings* and 'Some Considerations about Structural Architecture', all the quotations by Nervi's writings have been translated from Italian by the authors.

3 Among the recent monographs on Nervi, see Olmo and Chiorino (2010); Bianchino and Costi (2012); Antonucci, Trentin, and Trombetti (2014); Gargiani and Bologna (2016); and Leslie (2017). A collection of his articles, which was the first to demonstrate Nervi's significant influence within the pre- and post-war Italian and international architectural debate, was edited by Gabriele Nervi (Nervi 2014a).

4 The images are collected in the Album and Fotoschede sections of the Archivio Pier Luigi Nervi (MAXXI Museo nazionale delle Arti del XXI secolo, Roma, Collezione MAXXI Architettura).

5 Quotations from Vitruvius can be found in many of Nervi's writings, beginning with his first book *Scienza o arte del costruire?* (Nervi 1945: 37).

6 On the definition of type and its analysis, the Spanish architect Carlos Martí Arís asserted that 'it's better to assimilate the typological analysis to etymology than to classification' (Arís 1994: 49).

7 See also the introduction by Gabriele Neri to the new edition of *Scienza o arte del costruire?* (Nervi 2014b).

8 Nervi's invention of moveable ferrocement formworks, used for the first time in the Manifattura Tabacchi (Tobacco Warehouse) in Bologna (1949–57) helped create a smooth surface that needed no extra finishing and thus no extra work (Gargiani and Bologna 2016: 229–30; Antonucci, Trentin, and Trombetti (forthcoming).

9 On the construction of the halls, see Comba (2012: 130); on the structure of Hall B, see Lenticchia, Ceravolo, and Antonaci (2018).

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The authors have no competing interests to declare.

Author Informations

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All the quotations from Nervi's writings and other Italian sources have been translated from the Italian by the authors, with the exception of those taken from *Aesthetics and Technology in Buildings*.

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